

# A-Train Mission Operations Working Group

## CALIPSO Mission Status

Mike Cisewski  
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October 24, 2007





# Introduction



***The CALIPSO satellite is operating in fine-pointing mode with the three CALIPSO science instruments in data acquisition mode.***

- October 24<sup>th</sup>, 2007, is the 544<sup>th</sup> day on-orbit
- Mission Data Collection (September 1, 2007) is 94.1%
- All Spacecraft & Payload systems are performing well
- CALIPSO Laser Performance is Excellent
  - Laser Energy Trends Stable
- Initial Data Release Occurred December 8, 2006
- Major data release planned in November 2007



# Spacecraft Status



- Spacecraft (Platform) performance continues to be excellent

Except the following incidents/activities, the system availability was satisfying:

- Hubble Space Telescope avoidance :

- Payload laser emission is cut off whenever there is a CALIPSO over flight of Hubble (few seconds)
- Occurrences : 10 times since launch

- Solar Flares :

- Payload is shut off in case of solar flares
- Occurrence : Once from 2006/12/06 to 2006/12/19, 312h

- GPS anomaly :

- Due to GPS constellation problem, Platform may switch to CC REDUCED mode.  
=> patch for this problem is under validation
- Occurrence : third time (2006/11/11, 2007/02/01, 19/07/07)

- Maneuvers : Reduced mode for payload during maneuver

- Occurrence : 14 since launch



# Spacecraft Status



## ■ Platform parameters are nominal

### – Power Supply

- Overall Power System Assessment is as expected close to 550 W max

### – Command and Control

- Command-Control status is nominal

### – AOCS

- AOCS equipments behavior is nominal. One noticeable anomaly : Reduced mode due to GPS constellation anomaly. AOCS control law work nominally

### – Thermal

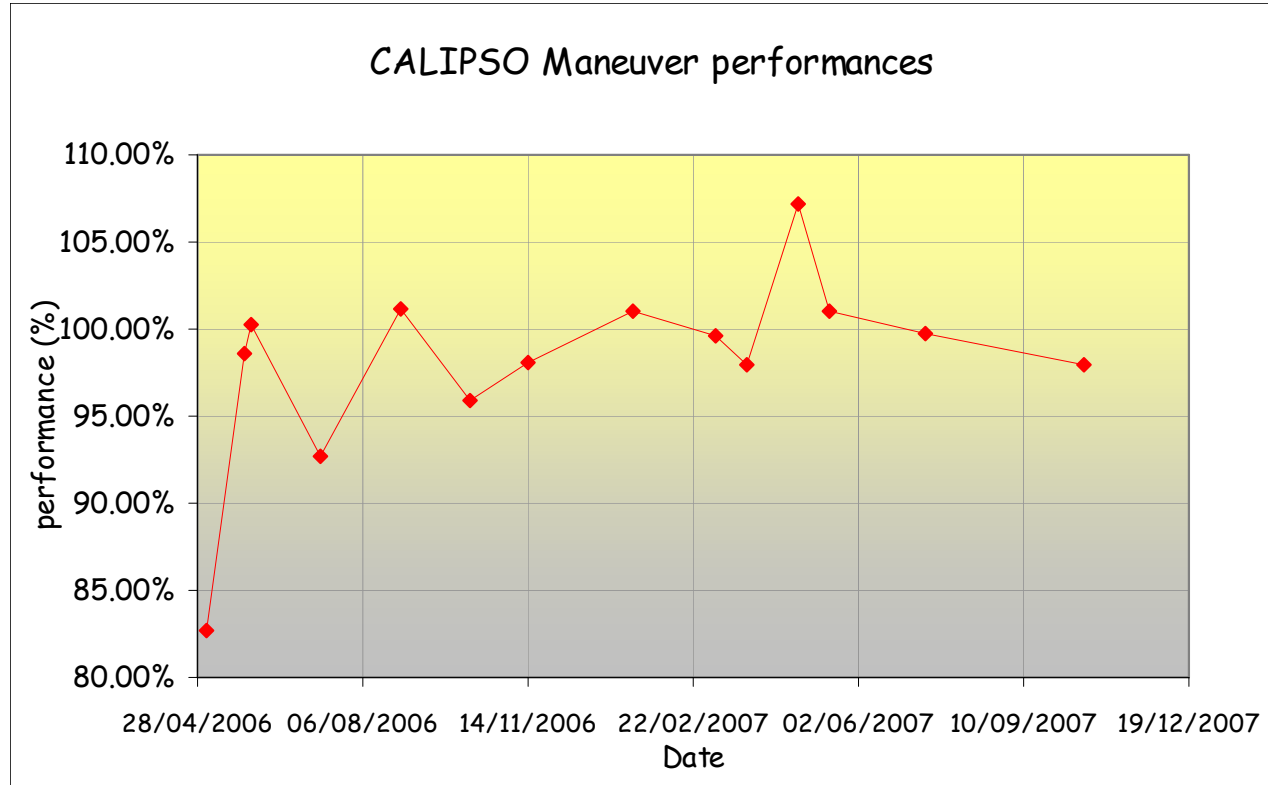
- All equipments in their specified temperature range
- PF thermal line heating needs close to the expected ones.
- No sign of aging



# Maneuver Performance



Maneuver Performance continues to be excellent



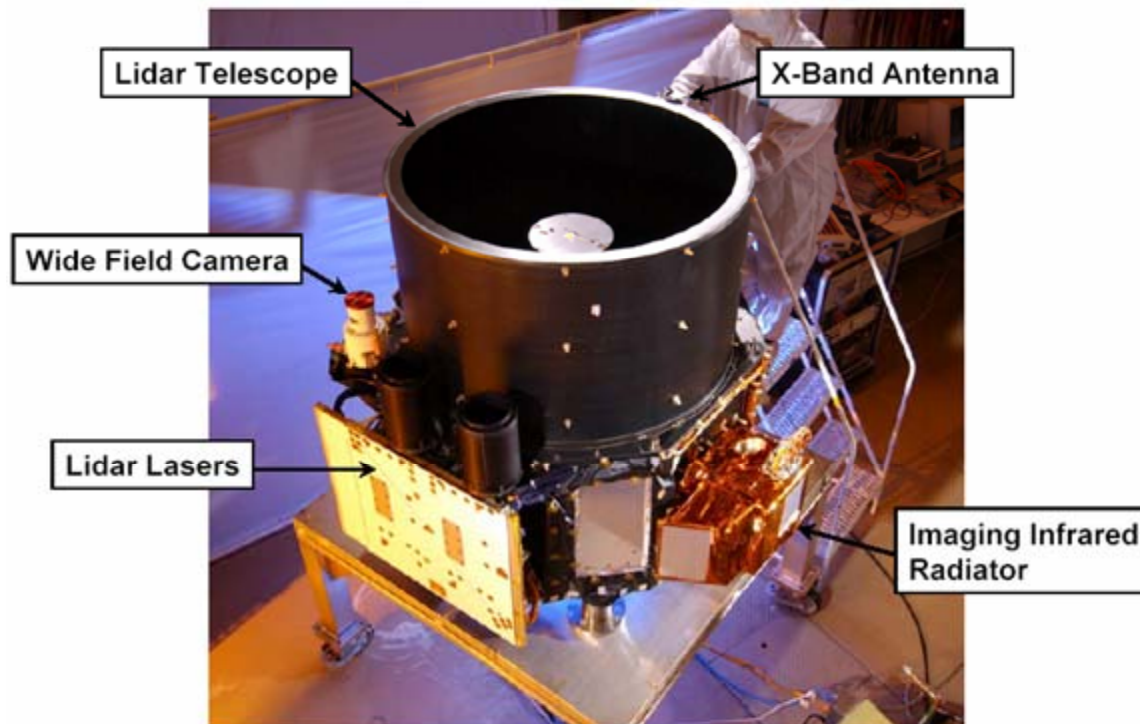
***Coordination process with CloudSat and A-train well understood and mature***



# Payload Status



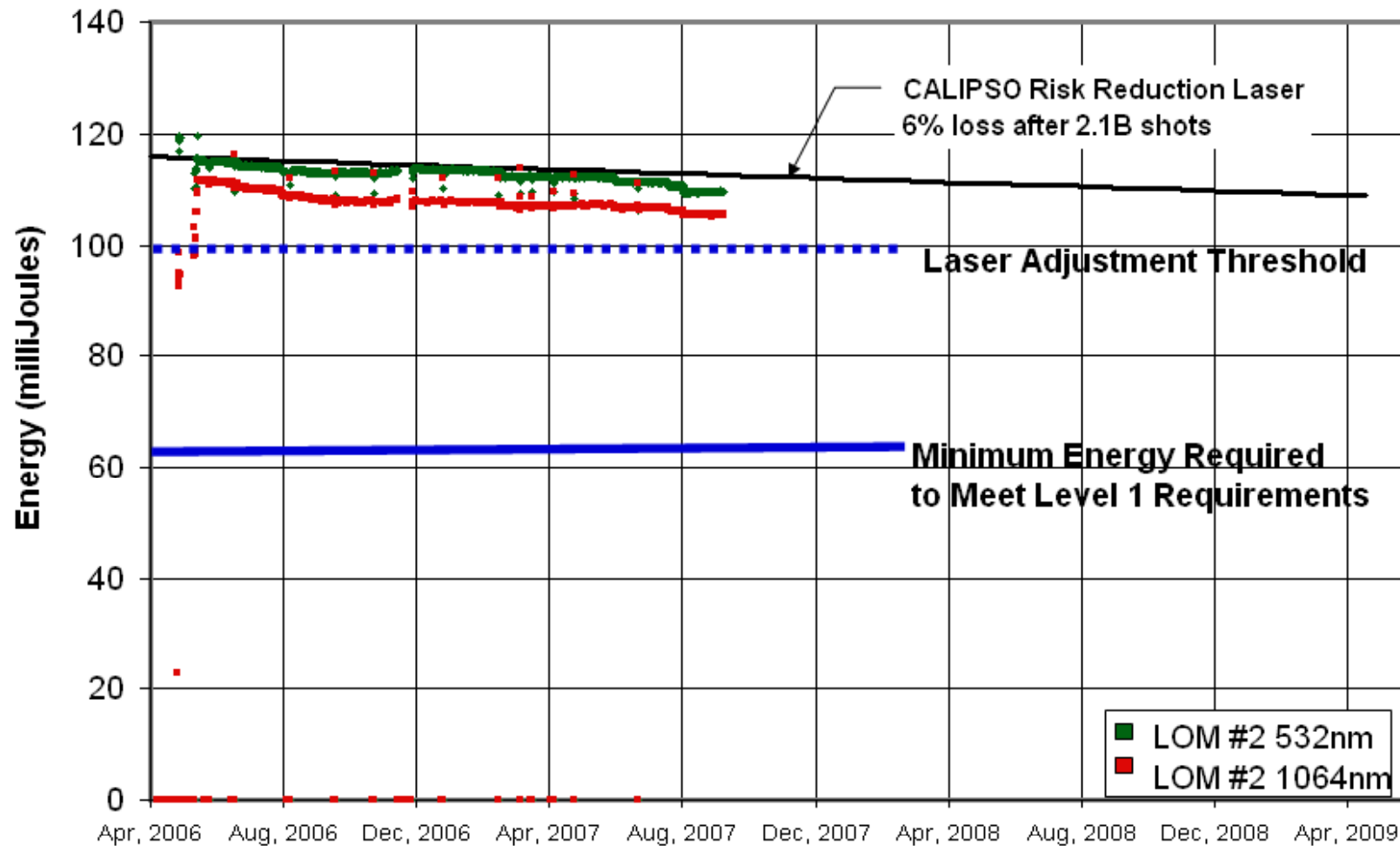
- CALIPSO science instrument performance continues to be excellent
  - CALIOP LIDAR
  - Imaging Infrared Radiometer
  - Wide Field Camera







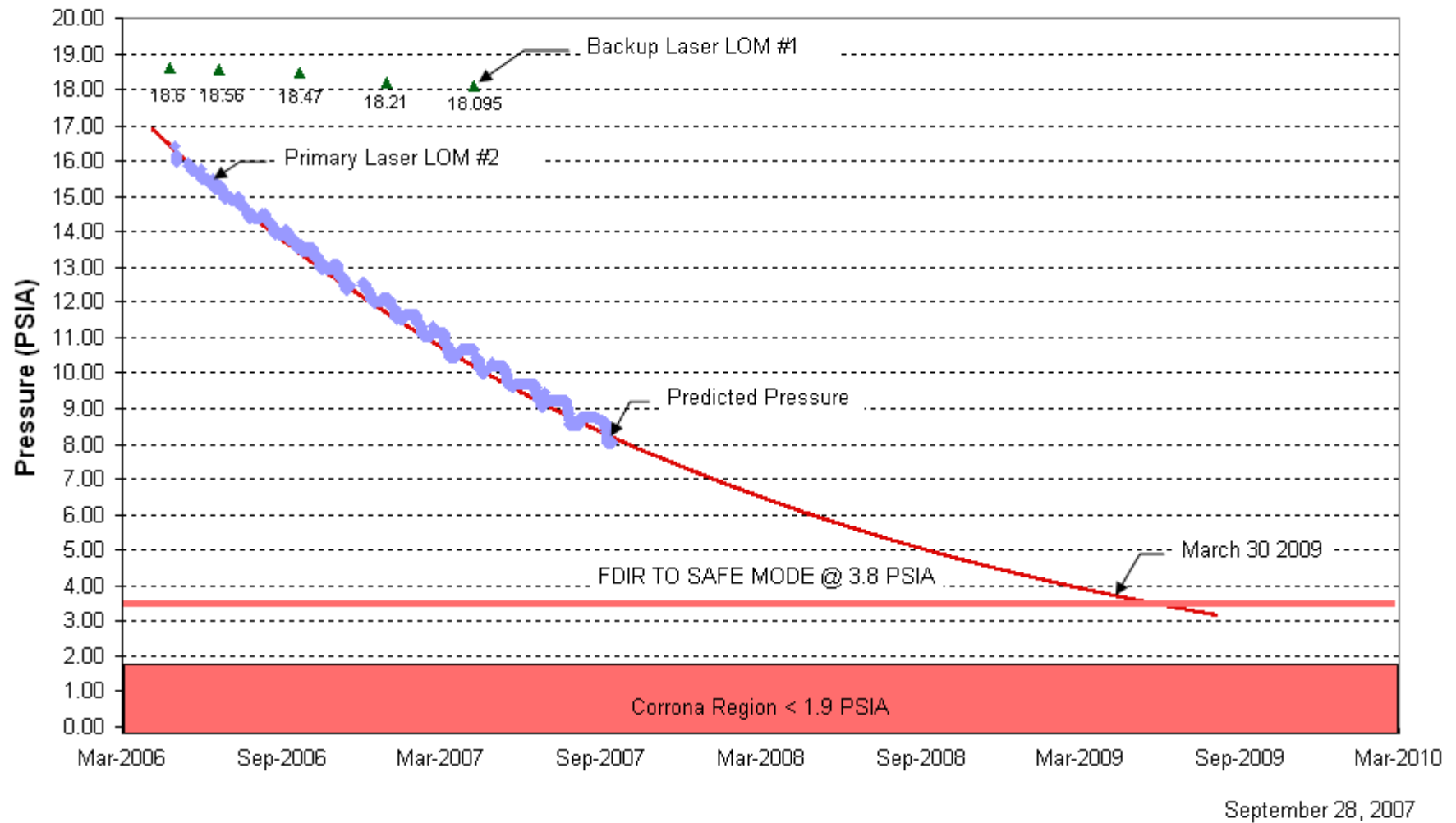
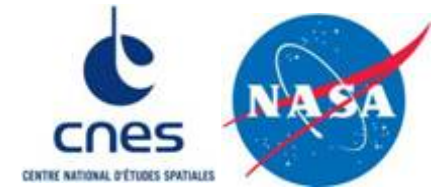
# CALIPSO Laser Performance



September 28, 2007



# Laser Pressure



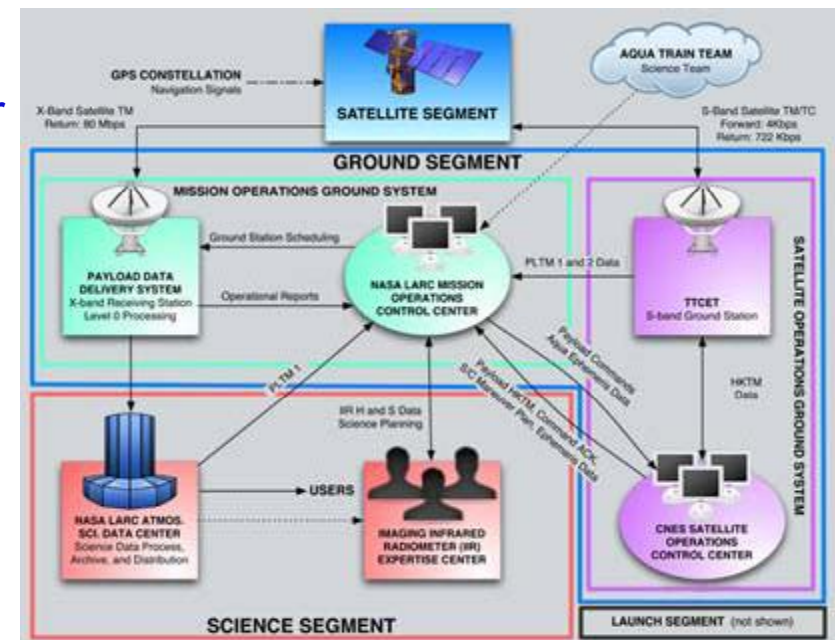




# Ground Network Status



- CALIPSO ground network performance continues to be excellent
  
- CNES provided elements
  - Spacecraft Operations Control Center
  - S-band ground network
  
- NASA provided elements
  - Mission Operations Control Center
  - X-band ground network
  - Atmospheric Science Data Center





# Summary



- Overall mission performance is excellent
  - Spacecraft
  - Payload
  - Ground Network
  
- NASA and CNES continue working well as an integrated team
  
- CALIPSO science results are spectacular

# *Afternoon Constellation Mission Operations Working Group - October 2007*

Lessons Learned during the Inclination  
Maneuvers - CALIPSO





# *Inclination Maneuver Sequence Planning*



- The Inclination Maneuver Adjust plans were created with the understanding that the maneuver sequence may be halted at any time.
  - This planning approach proved beneficial when Aqua required the sequence to be terminate in the Fall of 2006 and suspended in the Spring of 2007.
- A-Train planning meeting and teleconferences ensured that the documented maneuver plans and contingency agreements were well understood by all parties.



# Sequence Execution



- Regular A-Train teleconferences have allowed the train members to understand the needs and concerns of other train members.
- CALIPSO/CloudSat post maneuver teleconferences are needed for CloudSat to maintain formation flying by verifying CALIPSO maneuver performance and data product exchange.
- The early termination of Aqua maneuvers:
  - required significant additional work and coordination to replan the maneuver sequence
  - Increased constellation risk because additional maneuvers were required during the Spring 2007 sequence



# A-Train Mission Operations Working Group

## CALIPSO 2009 Inclination Maneuver Planning

**Mike Cisewski  
Nadège Queruel**

**October 24, 2007**







# *Introduction*



***CALIPSO's Spring 2009 Inclination Maneuver plans will be "finalized" as part of the 2009 senior review proposal***

***Based on current information, CALIPSO anticipates maintaining its current A-train location***

***Planning considerations include (but are not limited to):***

***CALIPSO health and operating margins***

***Precession discussion***

***Aqua plans and status***

***CloudSat plans and status***

***Parasol plans and status***

***Glory plans and status***

***Objective is to ensure CALIPSO's operational plans and location return optimal A-train science***



# Maneuver Execution



***CALIPSO anticipates executing a nominal inclination maneuver sequence similar to the Fall 2006 maneuver plan***

***Fewer larger burns are more efficient for CALIPSO***

*Science Availability*

*Workload*

***CALIPSO intends to retain the A-team:***

***Christophe Ferrier, Laurie Mann, Jean Fourcade***

***CALIPSO anticipates an updated constellation maneuver plan***

***CALIPSO anticipates development of a nominal maneuver predicted ephemeris***

***CALIPSO anticipates some participation in an A-train maneuver simulation***



# *Impact Studies*



- In order to confirmed that CALIPSO can follow the A-Train after next inclinaison (2009) maneuver some detailed studies should be done :
  - Detailed mission analyses taking into account :
    - Duration of extended mission
    - Precess or not precess at the end ?
    - Solar activities : impact on the duration of the mission
  - Platform experts analyses
    - Thermal control of the platform
    - Power system (particulary solar arrays aging..)
    - Impacts on Command control
    - Impacts on AOCS

# A-Train Mission Operations Working Group

To Be or Not to Be (Precess or Not to Precess)  
That is the question?

Carol Larigauderie  
Chip Trepte  
Nadege Queruel  
Mike Cisewski

October 24, 2007



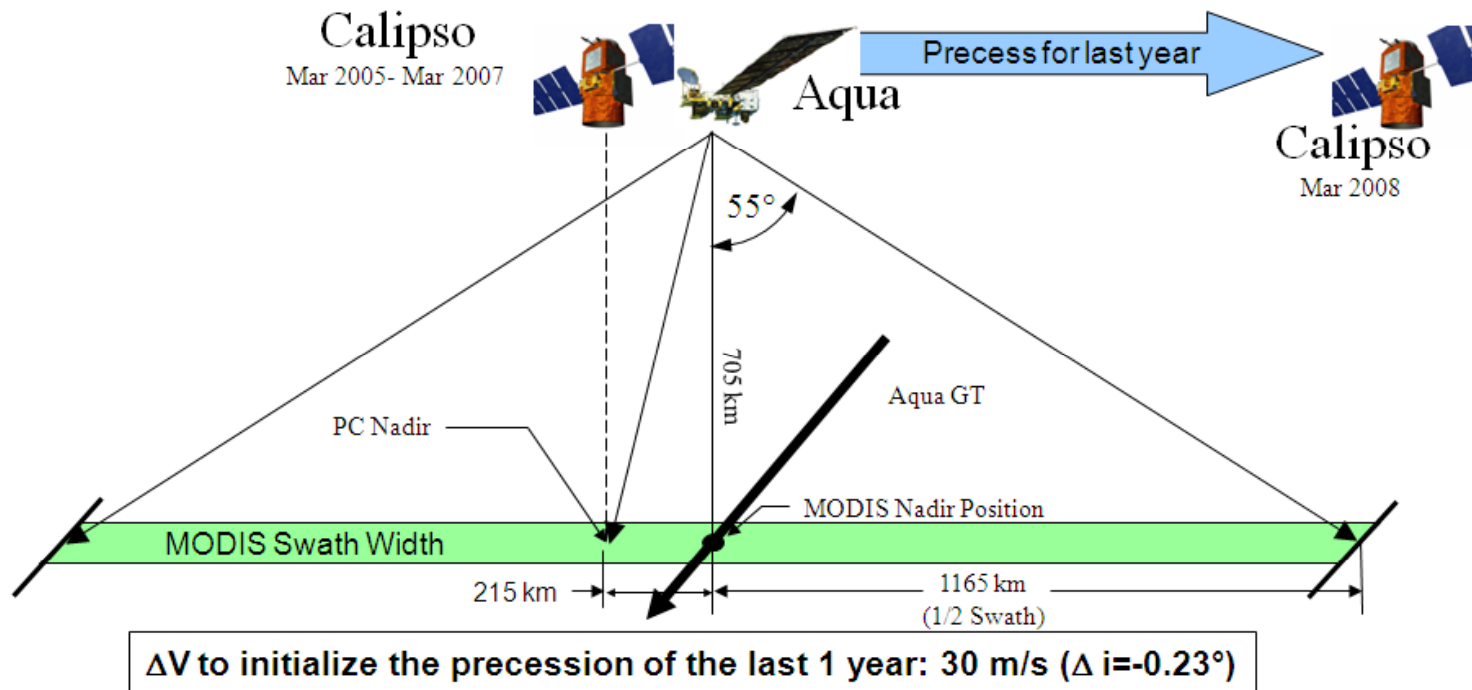


# Background



## The original three (3) year CALIPSO proposal included:

- Two years of operation 215 km east of the Aqua sub-satellite point
- A precession across the MODIS swath in year 3
- First two years: follow Aqua  $\Rightarrow$  Ascending Nodal Crossing: Aqua  
MLT + 73s + 9 min
- Last one year: precess over  
Modis western swath  $\Rightarrow$  Ascending Nodal Crossing:  
precesses to 12:52 over one year





## Background



***This plan is being re-evaluated with the following considerations***

1. Does precession across the MODIS swath in Year 3 return the best CALIPSO and A-train science?
  - Considering CloudSat extended mission approved
  - Considering CALIPSO mission life looks much longer than 3 years
2. Can CALIPSO continue to operate at 215 km east position indefinitely?
  - Are satellite system capacity /margins adequate?
3. What is best use of expendables for an extended mission?
  - The precession maneuver is costly from a fuel perspective with marginal fuel reserves to stop CALIPSO motion as proposed.



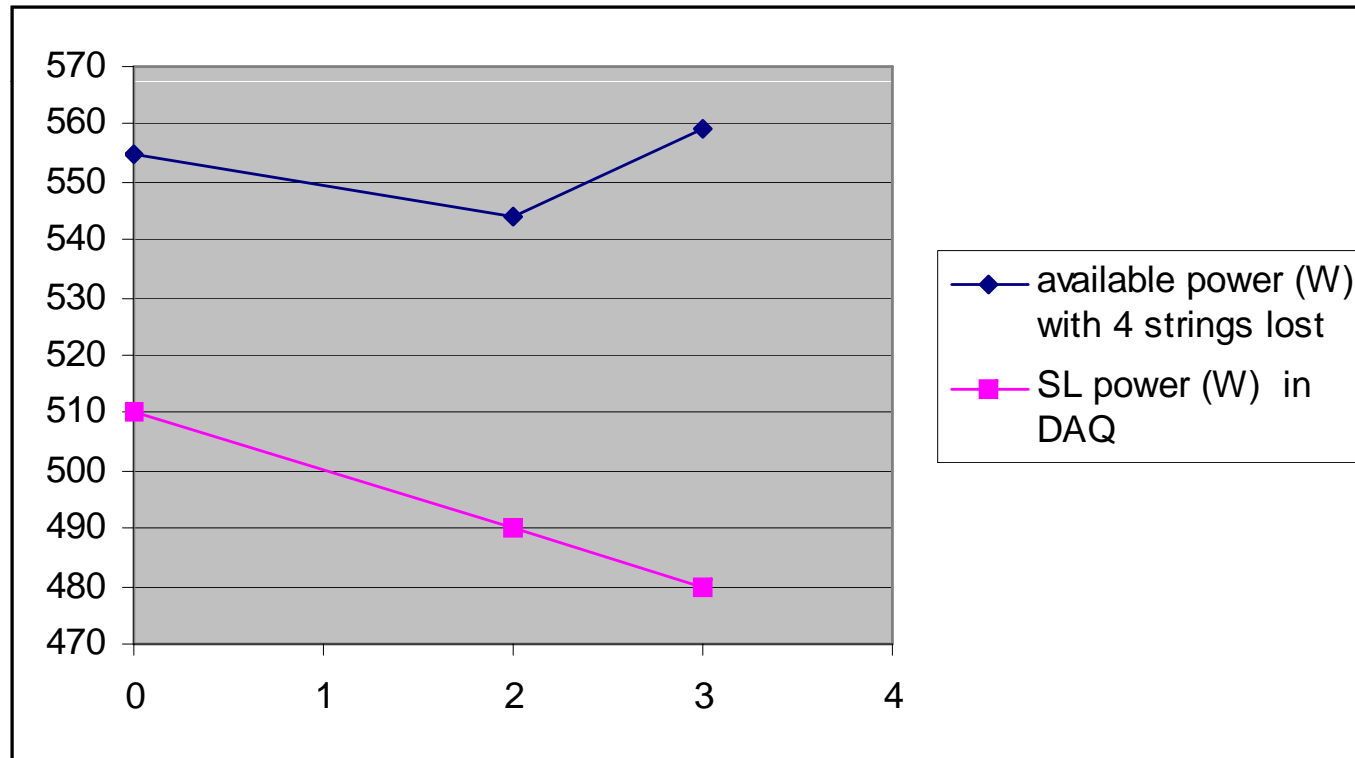


## Satellite system capacity and margin at 215 km east



CNES has completed a technical assessment to verify extended operation at our current location is possible

**Sample: Current power consumption versus power availability (TBC)**





# Expendables



***Adequate fuel budget margin exists without the precession maneuver***

|   |                    |
|---|--------------------|
| Delta V (beginning of Life m/s)           | 90.1 +/- 3.3       |
| Actual consumption + predicted budget m/s | 62.6 +/-2.3        |
| Delta V margin m/s                        | <b>27.6 +/-1.0</b> |

## ***Fuel Budget Details***

| <b>Dv Budget (m/s)</b> | predicted | actual consumption | Percent |
|------------------------|-----------|--------------------|---------|
| Orbit acquisition      | 6.99      | 7.02               | 100.5%  |
| inclination A-train    | 12        | 11.17              | 93.1%   |
| SMA DMU                | 1.44      | 0.21               | 14.3%   |
| SMA braking            | 0.3       | 0                  | 0%      |
| inclination correction | 0.35      | 0                  | 0%      |
| start precession       | 35        | 0                  | 0%      |
| EOL Decommission       | 8.5       | 0                  | 0%      |



# *Summary and Conclusions*



CALIPSO intends operate at its current location indefinitely

## 1. Coupled A-train science optimized

- CALIPSO and CloudSat coincident imaging
- Systematic A-train studies enhanced with stable constellation configuration

## 2. CALIPSO system margins are adequate

- Margins will be evaluated annually at the CALIPSO REVEX review
- CALIPSO will provide Six Months (TBC) notice of any necessary changes

## 3. CALIPSO has a significant fuel reserve at its current A-train location

# A-Train Mission Operations Working Group

## CALIPSO pitch change status and plans

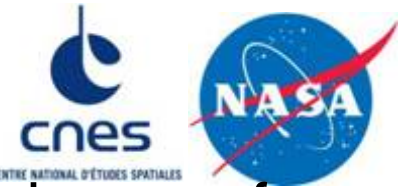
**Chip Trepte  
Mike Cisewski  
Ron Verhappen  
Nadège Queruel  
Emilie Limasset**

**October 24, 2007**





# *Introduction*



“Characterization of the radiative effects of clouds is one of the primary science objectives of CALIPSO. We are currently trying to understand the changing climate of the Arctic. Clouds play a key role in that they control the surface radiation budget in the polar regions, yet passive remote sensing retrievals of cloud properties in the polar regions are very difficult and highly uncertain. CALIPSO offers the chance to observe the true distribution and properties of polar clouds and assess current passively-derived polar cloud climatologies, problems that cannot be effectively addressed without CALIPSO..... Therefore, we must do the best job we can at characterizing the characteristics of polar clouds relevant to radiative effects. It is necessary to eliminate the current effects from oriented particles on CALIOP nadir signals in order to meet these objectives.”

David Winker, CALIPSO Principal Investigator commenting on the effects of horizontally oriented ice crystals observed at our current orientation of  $0.3^\circ$



# *Introduction*



To evaluate techniques to mitigate the effects of oriented crystals, CALIPSO has operated at a  $3^\circ$  pitch orientation twice

- November 6, 2006 until November 15, 2006
- August 21, 2007 until September 7, 2007

Analysis of measurements at  $3^\circ$  show the change in satellite orientation was very effective in reducing the effects of oriented plates

Based on these results and extensive consultation within the science community, the CALIPSO principal investigator is requesting that we change our orientation to  $3^\circ$  as soon as possible





# *Impacts of Pitch Change*



A joint CNES-NASA technical assessment (PC-SYS-504) of operation at a 3° pitch has been completed.

The purpose of the assessment was to ensure operation at 3 ° pitch full time is safe and to identify any necessary system configuration changes

- CNES presentation outlining satellite findings from Emilie Limasset
- NASA presentation outlining payload findings from Ron Verhappen

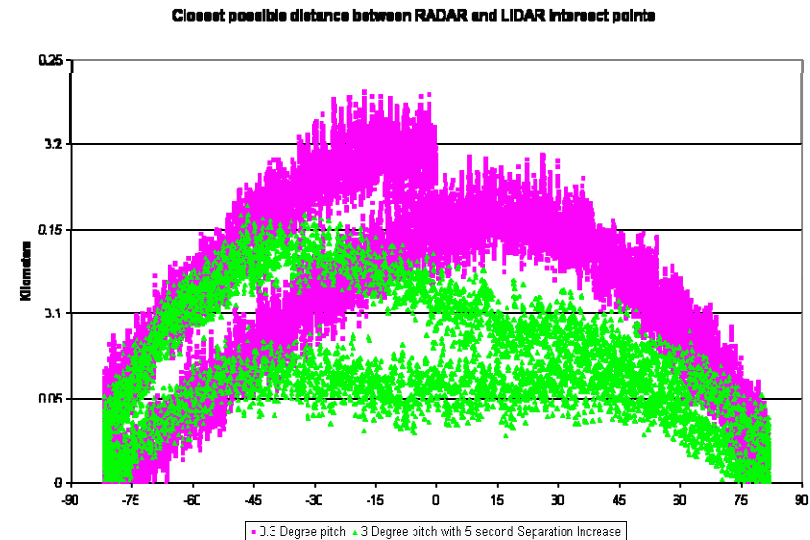
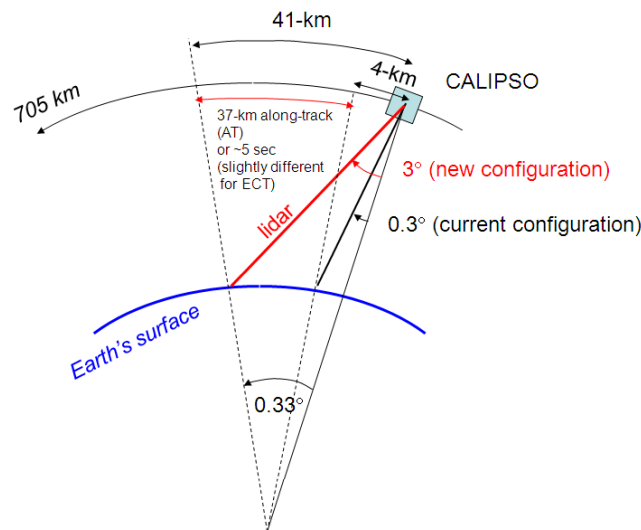


# Impacts of Pitch Change



The change in pitch from  $0.3^\circ$  to  $3.0^\circ$  changes CALIPSO's LIDAR spot location on the ground

- Unaccounted, the change in spot location adversely affects CALIPSO – CloudSat footprint overlap which is currently  $> 90\%$
- CALIPSO and CloudSat performed a joint analysis which recommended increasing the separation between CALIPSO and CloudSat by 5 seconds as a low risk technique to maintain the excellent footprint overlap





## *Detailed Implementation*



The following steps required to maintain footprint overlap have been discussed and agreed to in principal.

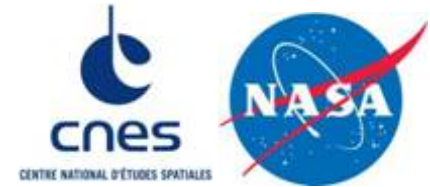
- CloudSat will fly 5 seconds further ahead of CALIPSO
- Aqua has agreed to permit CloudSat to fly slightly closer to Aqua
- CCS will be updated to reflect CloudSat's new control box location

Constellation implementation steps have been outlined in PC-SYS-505:  
CALIPSO 3° Pitch Change Implementation Plan

- A first draft release of the plan was issued on July 24, 2007
- A second draft release of the plan has been in review since September 17, 2007
- MOWG goal is to obtain all necessary signatures



## Detailed Implementation



Baseline implementation approach is outlined below:

| Time                                     | Organization           | Operation   |
|--|------------------------|---|
| Maneuver – 30 days                       | CALIPSO*               | Notification to Constellation that permanent pitch change is planned  |
| Maneuver – 21 days                       | CloudSat               | Confirmation CloudSat can support pitch change as proposed  |
| Maneuver – 21 days                       | CCS                    | Confirmation CCS can support pitch change as proposed   |
| Maneuver – 21 days -<br>Maneuver -7 days | CALIPSO &<br>CloudSat  | Establish detailed maneuver plan and timeline   |
| Maneuver – 7 days                        | CALIPSO &<br>CloudSat* | Baseline detailed maneuver plan and timeline  |
| Maneuver                                 | CALIPSO*               | Execute CALIPSO drag make-up maneuver.<br>CALIPSO/CloudSat post maneuver teleconference conducted at 1500 UTC.                          |
| Maneuver < x days                        | CALIPSO**              | CALIPSO changes the nominal pitch angle from 0.3 degrees to 3 degrees.  |
| Maneuver +x days                         | CloudSat               | Depending on the maneuver magnitude, CloudSat times its drag makeup maneuver so it will have about 17.5 seconds separation from CALIPSO |
| Maneuver + x days                        | CCS*                   | Constellation coordination group changes the alert system to reflect the new configuration.   |

\* Coordination teleconference planned with CALIPSO, CloudSat, Aqua, ESMO, and CCS participation

\*\* Although it is not desirable, CALIPSO reserves the right to implement the 3 degree pitch change independently of the coordinated maneuver sequence outlined. Measurements at the 3 degree pitch were successfully performed in November 2006 and August/September 2007 as part of the CALIPSO science assessment. There are no constellation safety impacts with independent CALIPSO operation at the revised pitch angle. Measurement coincidence with CloudSat will decrease, however, as outlined earlier.



## Final Details



Finally, the A-train cartoon will need to be updated to reflect the new constellation configuration

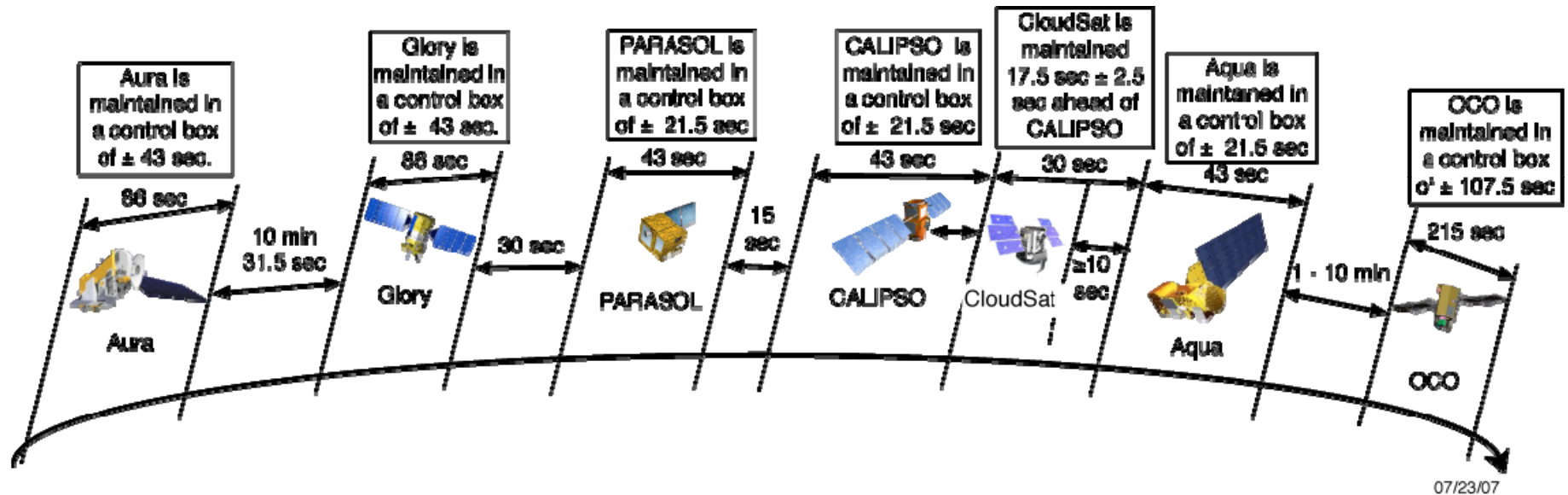


Illustration courtesy of Ed Hanka, NASA GSFC



# A-Train Mission Operations Working Group

## CALIPSO pitch change status and plans : Payload Point of View

Ron C. Verhappen  
SSAI  
October 25, 2007







# *Introduction*



3° pitch orientation performed twice :

- November 6 until November 15, 2006
- August 21 until September 7, 2007

Payload Analysis :

- Analysis carried out by Payload Engineer and approved by the Development Systems Engineering Team



# *Introduction*



## ■ Payload Systems assessed

### –LIDAR

- Laser transmitter
- Receiver

### –Wide Field Camera

### –Imaging infrared Radiometer

### –Payload Controller/X-Band Transmitter

### –Power Consumption

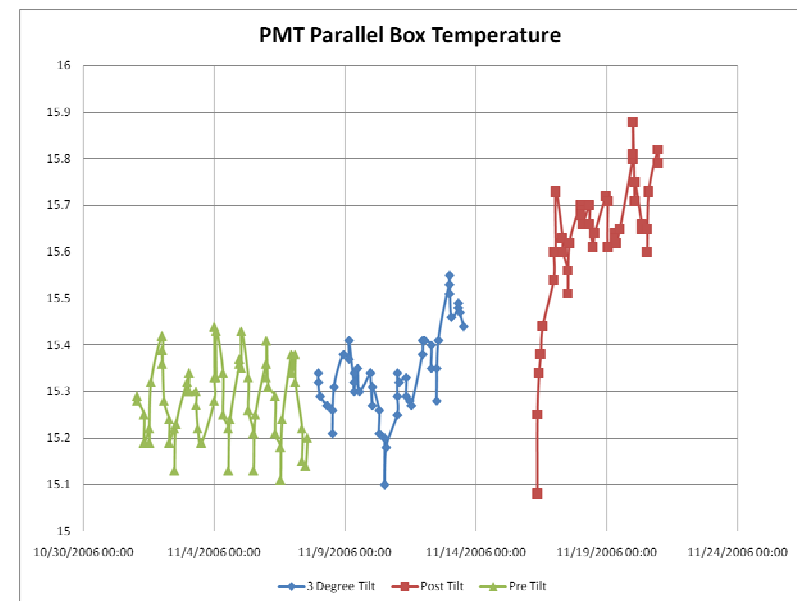
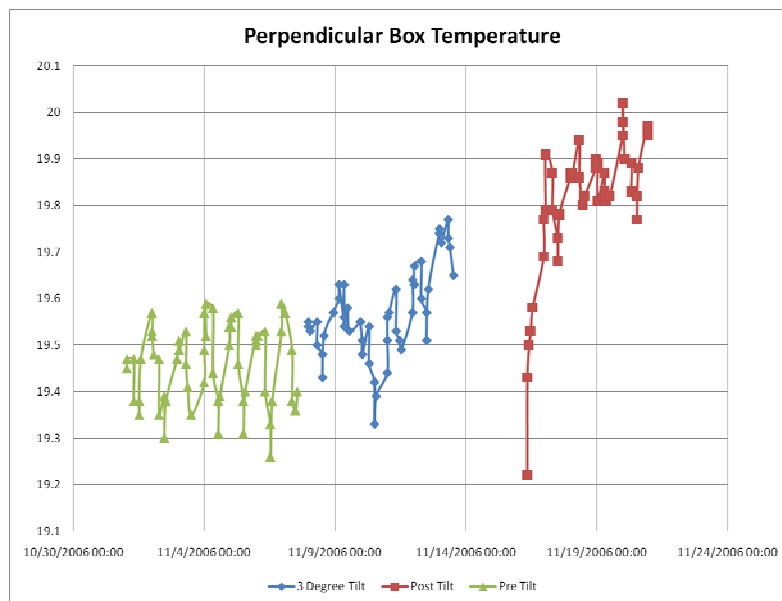
### –Thermal System



# LIDAR



- The change in pitch introduces a small bias in the surface height (~166 meters)
  - accounted for using an updated configuration file
- Detector temperatures continue to follow BETA angle
- 5 Laser Temperatures showed no change



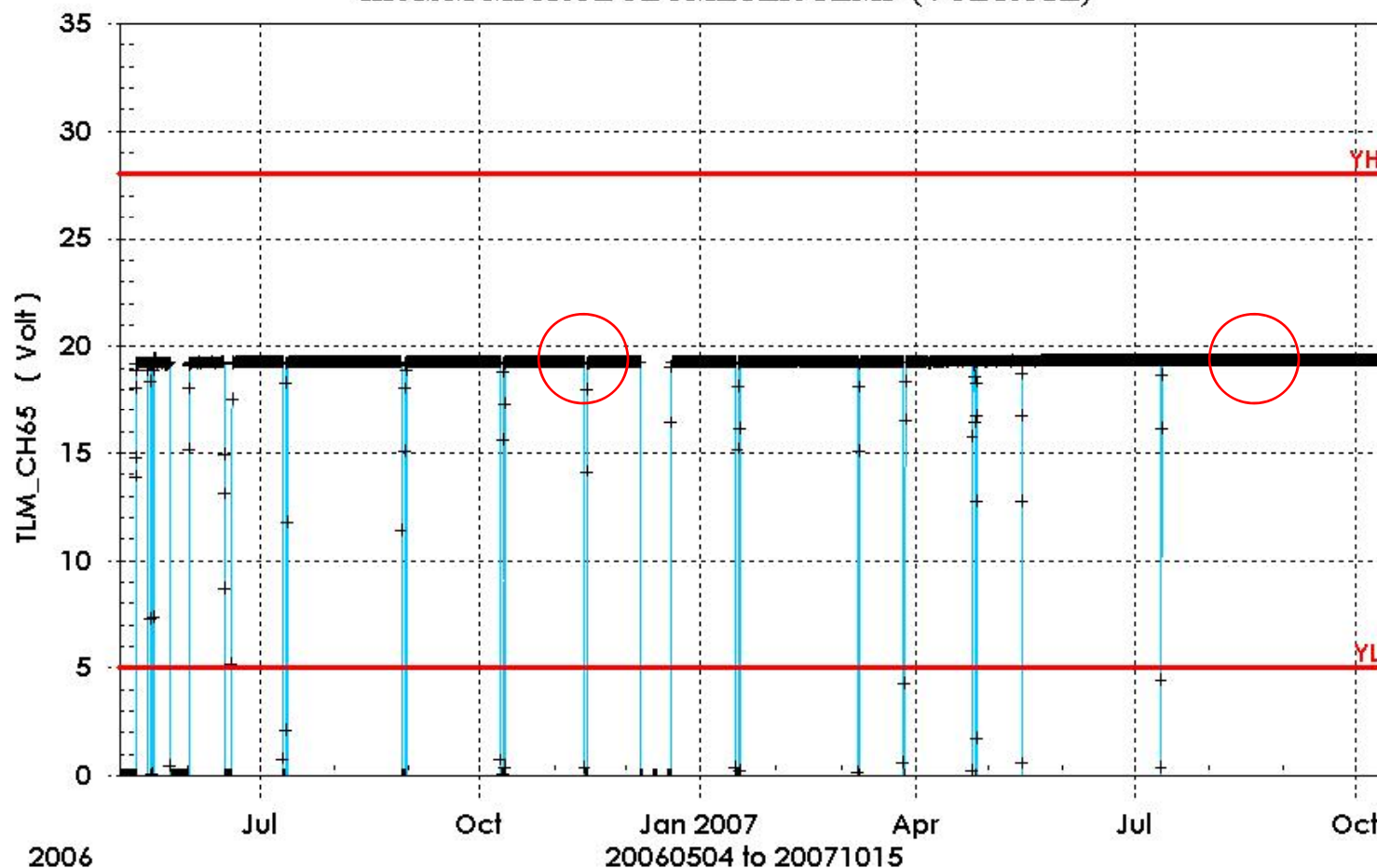


# Imaging Infrared Radiometer



- IIR Focal plane temperature remains constant

General Time Trend of CALIPSO Data  
IIR ISM MICROBOLOMETER TEMP (VOLTAGE)

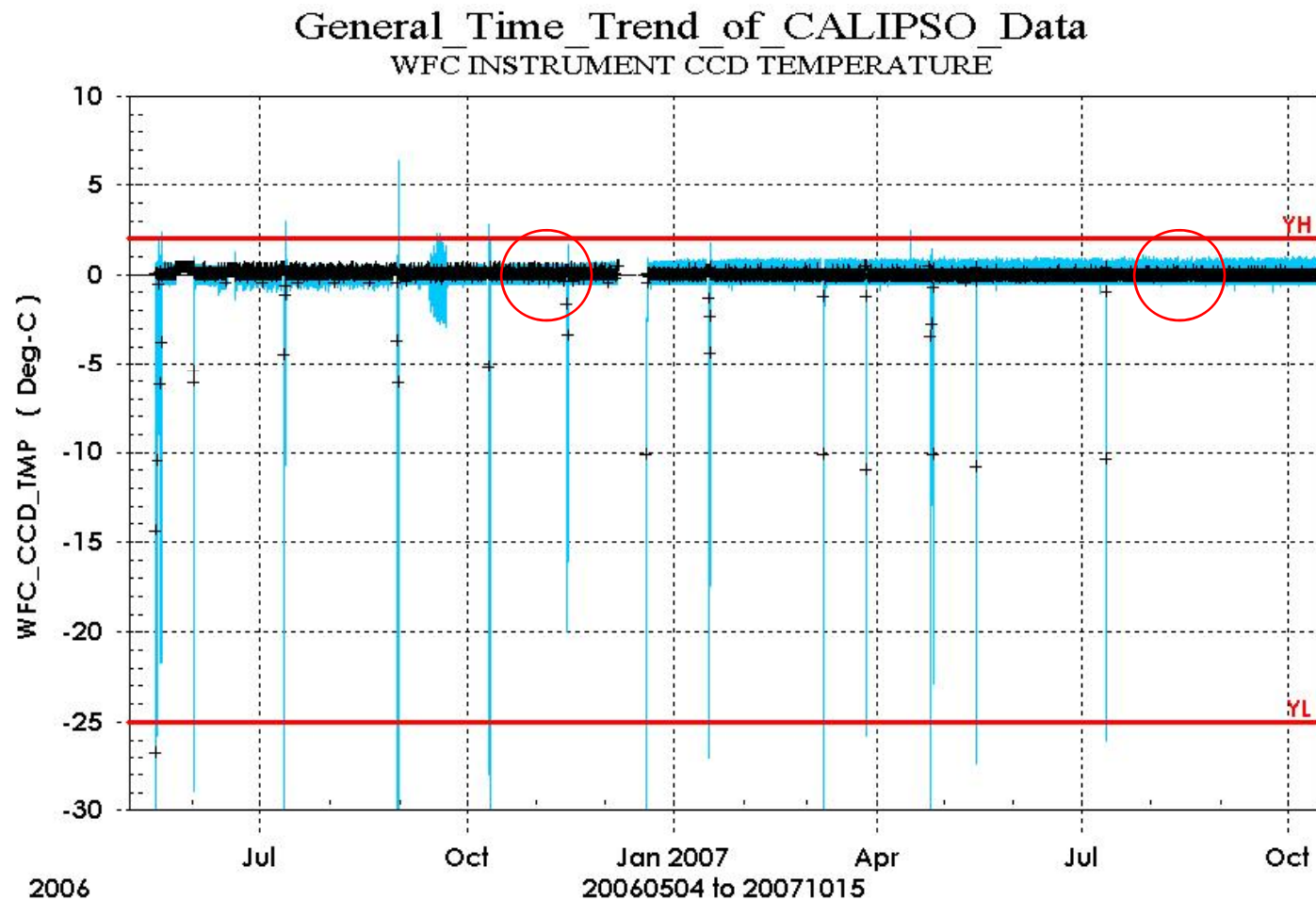




# Wide Field Camera



- WFC CCD temperature is thermally controlled
  - Pitch change has no affect



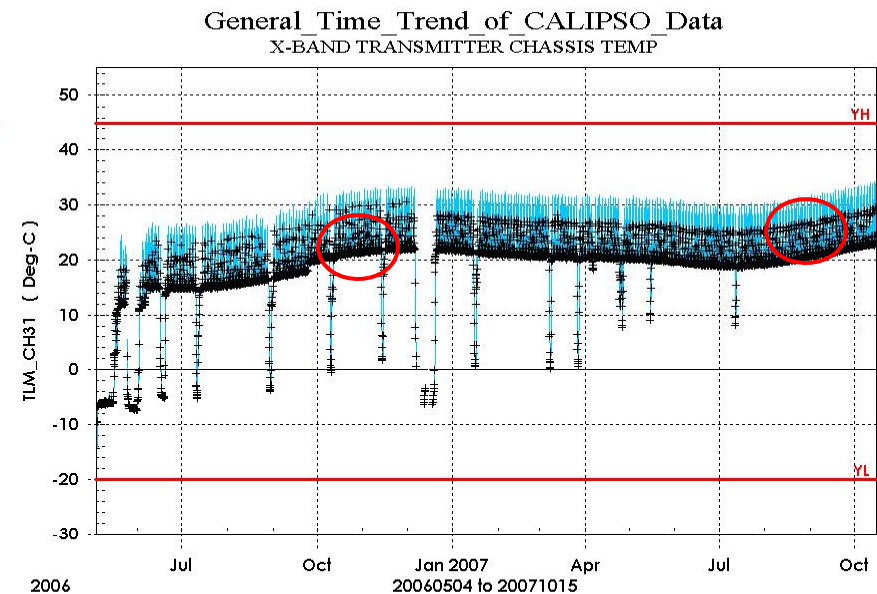
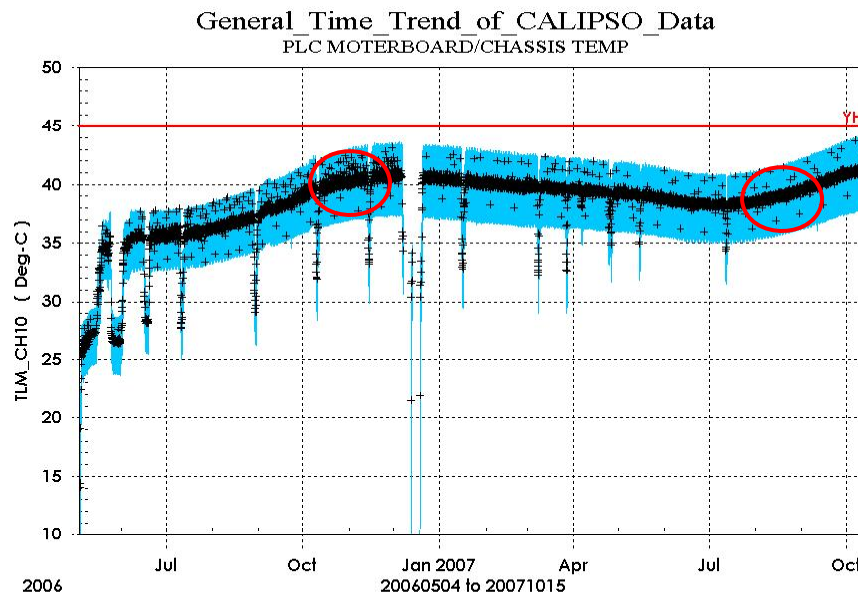




# Payload Controller/X-band Transmitter



- Payload controller computer temperature remains constant
- X-band Antenna
  - Omni directional no operational changes required

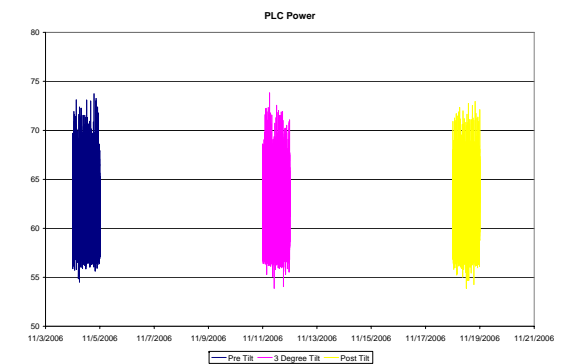
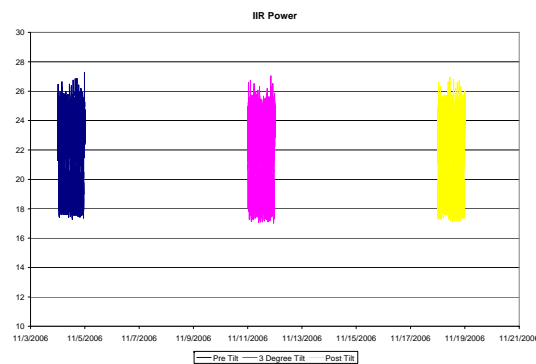
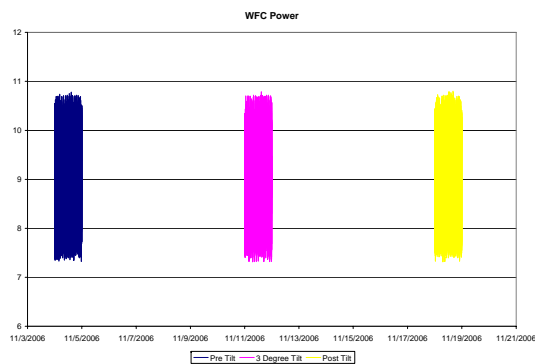
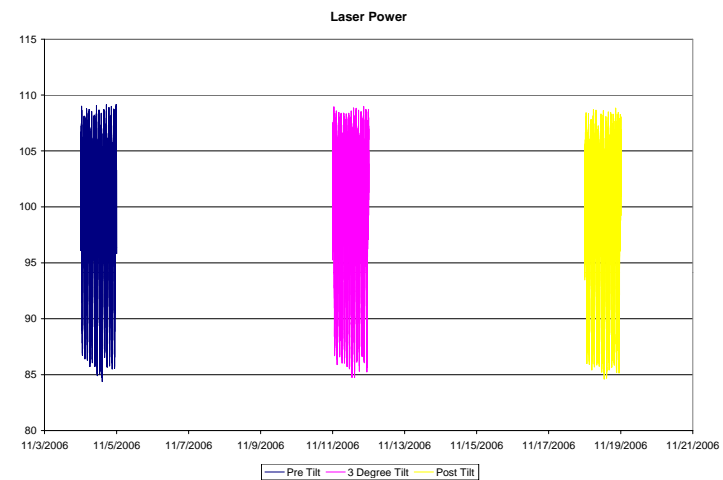
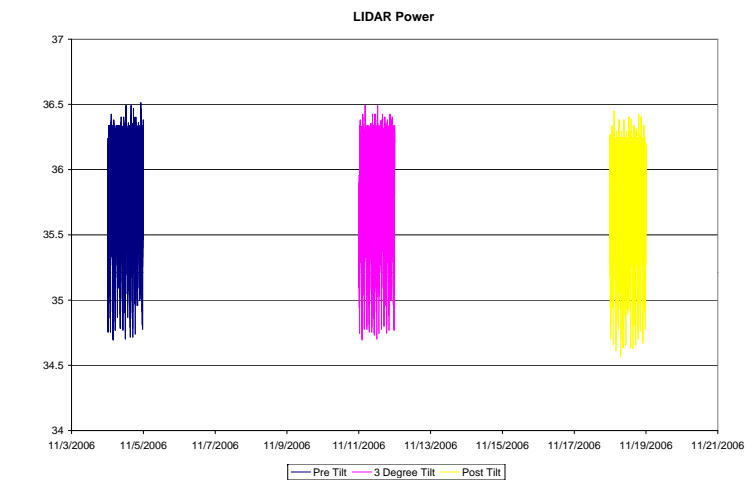




# Payload Power Consumption



- No changes to instrument power consumption





## *Summary*



### ■ Payload Telemetry Analysis Shows:

#### – LIDAR, IIR, WFC

- No affect do to pitch change

#### – Payload Power Consumption

- No Impacts

**Payload Systems are not affected by Pitch Change**